

SECONDARY ROCKS.

ERA OF THE CARBONIFEROUS FORMATION.

LAND FORMED.

COMMENCEMENT OF LAND PLANTS.

WE now enter upon a new great epoch in the history of our globe. There was now dry land. As a consequence of this fact, there was fresh water, for rain, instead of immediately returning to the sea, as formerly, was now gathered in channels of the earth, and became springs, rivers, and lakes. There was now a theatre for the existence of land plants and animals, and it remains to be inquired if these accordingly were produced.

The Secondary Rocks, in which our further researches are to be prosecuted, consist of a great and varied series, resting, generally unconformably, against flanks of the upturned primary rocks,

sometimes themselves considerably inclined, at others, forming extensive basin-like beds, nearly horizontal ; in many places, much broken up and shifted by disturbances from below. They have all been formed out of the materials of the older rocks, by virtue of the wearing power of air and water, which is still every day carrying down vast quantities of the elevated matter of the globe into the sea. But the separate strata are each much more distinct in the matter of its composition than might be expected. Some are siliceous or arenaceous (sandstones), composed mainly of fine grains from the quartz rocks—the most abundant of the primary strata. Others are argillaceous—clays, shales, &c., chiefly derived, probably, from the slate beds of the primary series. Others are calcareous, derived from the early limestone. As a general feature, they are softer and less crystalline than the primary rocks, as if they had endured less of both heat and pressure than the senior formation. There are beds (*coal*) formed solely of vegetable matter, and some others in which the main ingredient is particles of iron, (*the iron black band.*) The secondary rocks are quite as communicative with regard to their portion of the earth's history as the primitive were.

The first, or lowest, group of the secondary rocks is called the *Carboniferous Formation*, from the remarkable feature of its numerous interspersed beds of coal. It commences with the beds of the *mountain limestone*, which, in some situations, as in Derbyshire and Ireland, are of great thickness, being alternated with chert (a siliceous sandstone), sandstones, shales, and beds of coal, generally of the harder and less bituminous kind (*anthracite*), the whole being covered in some places by the millstone grit, a siliceous conglomerate composed of the detritus of the primary rocks. The mountain limestone, attaining in England to a depth of eight hundred yards, greatly exceeds in volume any of the primary limestone beds, and shews an enormous addition of power to the causes formerly suggested as having produced this substance. In fact, remains of corals, crinoidea, and shells, are so abundant in it, as to compose three-fourths of the mass in some parts. Above the mountain limestone commence the more conspicuous *coal beds*, alternating with sandstones, shales, beds of limestone, and ironstone. Coal is altogether composed of the matter of a terrestrial vegetation, transmuted by pressure. Some fresh-water shells have been

found in it, but few of marine origin, and no remains of those zoophytes and crinoidea so abundant in the mountain limestone and other rocks. Coal beds exist in Europe, Asia, and America, and have hitherto been esteemed as the most valuable of mineral productions, from the important services which the substance renders in manufactures and in domestic economy. It is to be remarked, that there are some local variations in the arrangement of coal beds. In France, they rest immediately on the granite and other primary rocks, the intermediate strata not having been found at those places. In America, the kind called anthracite occurs among the slate beds, and this species also abounds more in the mountain limestone than with us. These last circumstances only shew that different parts of the earth's surface did not all witness the same events of a certain fixed series exactly at the same time. There had been an exhibition of dry land about the site of America, a little earlier than in Europe.

Some features of the condition of the earth during the deposition of the carboniferous group, are made out with a clearness which must satisfy most minds. First we are told of a time when

carbonate of lime was formed in vast abundance at the bottoms of profound seas, accompanied by an unusually large population of corals and encrinites; while in some parts of the earth there were patches of dry land, covered with a luxuriant vegetation. Next we have a comparatively brief period of volcanic disturbance, (when the conglomerate was formed.) Then the causes favourable to the so abundant production of limestone, and the large population of marine acrita, decline, and we find the masses of dry land increase in number and extent, and begin to bear an amount of forest vegetation, far exceeding that of the most sheltered tropical spots of the present surface. The climate, even in the latitude of Baffin's Bay, was torrid, and perhaps the atmosphere contained a larger charge of carbonic acid gas (the material of vegetation) than it now does. The forests or thickets of the period, included no species of plants now known upon earth. They mainly consisted of gigantic shrubs, which are either not represented by any existing types, or are akin to kinds which are now only found in small and lowly forms. That these forests grew upon a Polynesia, or multitude of small islands, is considered probable, from similar vegetation being now found in such situations

within the tropics. With regard to the circumstances under which the masses of vegetable matter were transformed into successive coal strata, geologists are divided. From examples seen at the present day, at the mouths of such rivers as the Mississippi, which traverse extensive sylvan regions, and from other circumstances to be adverted to, it is held likely by some that the vegetable matter, the rubbish of decayed forests, was carried by rivers into estuaries, and there accumulated in vast natural rafts, until it sunk to the bottom, where an overlayer of sand or mud would prepare it for becoming a stratum of coal. Others conceive that the vegetation first went into the condition of a peat moss, that a sink in the level then exposed it to be overrun by the sea, and covered with a layer of sand or mud; that a subsequent uprising made the mud dry land, and fitted it to bear a new forest, which afterwards, like its predecessor, became a bed of peat; that, in short, by repetitions of this process, the alternate layers of coal, sandstone, and shale, constituting the carboniferous group, were formed. It is favourable to this last view that marine fossils are scarcely found in the body of the coal itself, though abundant in the shale layers above and below it; also

that in several places erect stems of trees are found with their roots still fixed in the shale beds, and crossing the sandstone beds at almost right angles, shewing that these, at least, had not been drifted from their original situations. On the other hand, it is not easy to admit such repeated risings and sinkings of surface as would be required, on this hypothesis, to form a series of coal strata. Perhaps we may most safely rest at present with the supposition that coal has been formed under both classes of circumstances, though in the latter only as an exception to the former.

Upwards of three hundred species of plants have been ascertained to exist in the coal formation; but it is not necessary to suppose that the whole contained in that system are now, or ever will be distinguished. Experiments shew that some great classes of plants become decomposed in water in a much less space of time than others, and it is remarkable that those which decompose soonest, are of the classes found most rare, or not at all, in the coal strata. It is consequently to be inferred that there may have been grasses and mosses at this era, and many species of trees, the remains of which had lost all trace of organic form before their substance sunk into the mass of which coal was formed.

In speaking, therefore, of the vegetation of this period, we must bear in mind that it may have comprehended forms of which we have no memorial.

Supposing, nevertheless, that, in the main, the ascertained vegetation of the coal system is that which grew at the time of its formation, it is interesting to find that the terrestrial botany of our globe begins with classes of comparatively simple forms and structure. In the ranks of the vegetable kingdom, the lowest place is taken by plants of cellular tissue, and which have no flowers, (*cryptogamia*,) as lichens, mosses, fungi, ferns, sea-weeds. Above these stand plants of vascular tissue, and bearing flowers, in which again there are two great subdivisions; first, plants having one seed-lobe, (*monocotyledons*,) and in which the new matter is added within, (*endogenous*,) of which the cane and palm are examples; second, plants having two seed-lobes, (*dicotyledons*,) and in which the new matter is added on the outside under the bark, (*exogenous*,) of which the pine, elm, oak, and most of the British forest-trees are examples; these subdivisions also ranking in the order in which they are here stated. Now it is clear that a predominance of these forms in succession marked

the successive epochs developed by fossil geology ; the simple abounding first, and the complex afterwards.

Two-thirds of the plants of the carboniferous era are of the cellular or cryptogamic kind, a proportion which would probably be much increased if we knew the whole Flora of that era. The ascertained dicotyledons, or higher-class plants, are comparatively few in this formation ; but it will be found that they constantly increased as the globe grew older.

The master-form or type of the era was the *fern*, or *breckan*, of which about one hundred and thirty species have already been ascertained as entering into the composition of coal.* The fern is a plant which thrives best in warm, shaded, and moist situations. In tropical countries, where these conditions abound, there are many more species than in temperate climes, and some of these are arborescent, or of a tree-like size and luxuriance.† The ferns of the coal strata have been of this magnitude, and that without regard to

* The principal families are named *sphenopteris*, *neuropteris*, and *pecopteris*.

† A specimen from Bengal, in the staircase of the British Museum, is forty-five feet high.

the parts of the earth where they are found. In the coal of Baffin's Bay, of Newcastle, and of the torrid zone alike, are the fossil ferns arborescent, shewing clearly that, in that era, the present tropical temperature, or one even higher, existed in very high latitudes.

In the swamps and ditches of England there grows a plant called the horse-tail (*equisetum*), having a succulent, erect, jointed stem, with slender leaves, and a scaly catkin at the top. A second large section of the plants of the carboniferous era were of this kind (*equisetaceæ*), but, like the fern, reaching the magnitudes of trees. While existing *equiseta* rarely exceed three feet in height, and the stems are generally under half an inch in diameter, their kindred, entombed in the coal beds, seem to have been generally fourteen or fifteen feet high, with stems from six inches to a foot in thickness. Arborescent plants of this family, like the arborescent ferns, now grow only in tropical countries, and their being found in the coal beds in all latitudes is consequently held as an additional proof, that at this era a warm climate was extended much farther to the north than at present. It is to be remarked that plants of this kind (forming two genera, the most abundant of which is the

calamites) are only represented on the present surface by plants of the same *family*: the *species* which flourished at this era gradually lessen in number as we advance upwards in the series of rocks, and disappear before we arrive at the tertiary formation.

The club-moss family (*lycopodiaceæ*) are other plants of the present surface, usually seen in a lowly and creeping form in temperate latitudes, but presenting species which rise to a greater magnitude within the tropics. Many specimens of this family are found in the coal beds; it is thought they have contributed more to the substance of the coal than any other family. But, like the ferns and equisetaceæ, they rise to a prodigious magnitude. The lepidodendra (so the fossil genus is called) have probably been from sixty-five to eighty feet in height, having at their base a diameter of about three feet, while their leaves measured twenty inches in length. In the forests of the coal era, the lepidodendra would enjoy the rank of firs in our forests, affording shade to the only less stately ferns and calamites. The internal structure of the stem, and the character of the seed-vessels, shew them to have been a link be-

tween single-lobed and double-lobed plants, a fact worthy of note, as it favours the idea that, in vegetable, as well as animal creation, a progress has been observed, in conformity with advancing conditions. It is also curious to find a missing link of so much importance in a genus of plants which has long ceased to have a living place upon earth.

The other leading plants of the coal era are without representatives on the present surface, and their characters are in general less clearly ascertained. Amongst the most remarkable are—the *sigillaria*, of which large stems are very abundant, shewing that the interior has been soft, and the exterior fluted with separate leaves inserted in vertical rows along the flutings—and the *stigmaria*, plants apparently calculated to flourish in marshes or pools, having a short, thick, fleshy stem, with a dome-shaped top, from which sprung branches of from twenty to thirty feet long. Amongst monocotyledons were some palms, (*flabellaria* and *næggerathia*,) besides a few not distinctly assignable to any class.

The dicotyledons of the coal are comparatively few, though on the present surface they are the most numerous sub-class. Besides some of doubt-

ful affinity, (*annularia*, *asterophyllites*, &c.,) there were a few of the pine family, which seem to have been the highest class of trees of this era, and are only as yet found in isolated cases, and in sandstone beds. The first discovered lay in the Craigeleith quarry, near Edinburgh, and consisted of a stem about two feet thick, and forty-seven feet in length. Others have since been found, both in the same situation, and at Newcastle. Leaves and fruit being wanting, an ingenious mode of detecting the nature of these trees was hit upon by Mr. Witham of Lartington. Taking thin polished cross slices of the stem, and subjecting them to the microscope, he detected the structure of the wood to be that of a cone-bearing tree, by the presence of certain "reticulations" which distinguish that family, in addition to the usual radiating and concentric lines. That particular tree was concluded to be an *araucaria*, a species now found in Norfolk Island, in the South Sea, and in a few other remote situations. The coniferæ of this era form the dawn of dicotyledenous trees, of which they may be said to be the simplest type, and to which, it has already been noticed, the *lepidodendra* are a link from the monocotyledons. The concentric rings of the Craigeleith and other coniferæ of this

era have been mentioned. It is interesting to find in these a record of the changing seasons of those early ages, when as yet there were no human beings to observe time or tide. They are clearly traced; but it is observed that they are more slightly marked than is the case with their family at the present day, as if the changes of temperature had been within a narrower range.

Such was the vegetation of the carbonigenous era, composed of forms at the bottom of the botanical scale, flowerless, fruitless, but luxuriant and abundant beyond what the most favoured spots on earth can now shew. The rigidity of the leaves of its plants, and the absence of fleshy fruits and farinaceous seeds, unfitted it to afford nutriment to animals; and, monotonous in its forms, and destitute of brilliant colouring, its sward probably unenlivened by any of the smaller flowering herbs, its shades uncheered by the hum of insects, or the music of birds, it must have been but a sombre scene to a human visitant. But neither man nor any other animals were then in existence to look for such uses or such beauties in this vegetation. It was serving other and equally important ends, clearing (probably) the atmosphere of matter noxious to animal life, and storing up mineral masses

which were in long subsequent ages to prove of the greatest service to the human race, even to the extent of favouring the progress of its civilization.

The animal remains of this era are not numerous, in comparison with those which go before, or those which come after. The mountain limestone, indeed, deposited at the commencement of it, abounds unusually in polypiaria and crinoidea; but when we ascend to the coal-beds themselves, the case is altered, and these marine remains altogether disappear. We have then only a limited variety of conchifers and shell mollusks, with fragments of a few species of fishes, and these are rarely or never found in the coal seams, but in the shales alternating with them. Some of the fishes are of a sauroid character, that is, partake of the nature of the lizard, a genus of the reptilia, a land class of animals, so that we may be said here to have the first approach to a kind of animals calculated to breathe the atmosphere. Such is the *Megalichthys Hibbertii*, found by Dr. Hibbert Ware, in a limestone bed of fresh-water origin, underneath the coal at Burdiehouse, near Edinburgh. Others of the same kind have been found in the coal measures in Yorkshire, and in the low coal

shales at Manchester. This is no more than might be expected, as collections of fresh water now existed, and it is presumable that they would be peopled. The chief other fishes of the coal era are named palæothrissum, palæoniscus, diperdus.

Coal strata are nearly confined to the group termed the carboniferous formation. Thin beds are not unknown afterwards, but they occur only as a rare exception. It is therefore thought that the most important of the conditions which allowed of so abundant a terrestrial vegetation, had ceased about the time when this formation was closed. The high temperature was not one of the conditions which terminated, for there are evidences of it afterwards; but probably the superabundance of carbonic acid gas supposed to have existed during this era was expended before its close. There can be little doubt that the infusion of a large dose of this gas into the atmosphere at the present day would be attended by precisely the same circumstances as in the time of the carboniferous formation. Land animal life would not have a place on earth; vegetation would be enormous; and coal strata would be formed from the vast accumulations of woody matter, which would gather in every sea, near the mouths of great rivers. On the exhaus-

tion of the superabundance of carbonic acid gas, the coal formation would cease, and the earth might again become a suitable theatre of being for land animals.

The termination of the carboniferous formation is marked by symptoms of volcanic violence, which some geologists have considered to denote the close of one system of things and the beginning of another. Coal beds generally lie in basins, as if following the curve of the bottom of seas. But there is no such basin which is not broken up into pieces, some of which have been tossed up on edge, others allowed to sink, causing the ends of strata to be in some instances many yards, and in a few several hundred feet, removed from the corresponding ends of neighbouring fragments. These are held to be results of volcanic movements below, the operation of which is further seen in numerous upbursts and intrusions of volcanic rock (trap). That these disturbances took place about the close of the formation, and not later, is shewn in the fact of the next higher group of strata being comparatively undisturbed. Other symptoms of this time of violence are seen in the beds of conglomerate which occur amongst the first strata above the coal. These, as usual, consist of frag-

ments of the elder rocks, more or less worn from being tumbled about in agitated water, and laid down in a mud paste, afterwards hardened. Volcanic disturbances break up the rocks; the pieces are worn in seas; and a deposit of conglomerate is the consequence. Of porphyry, there are some such pieces in the conglomerate of Devonshire, three or four tons in weight. It is to be admitted for strict truth that, in some parts of Europe, the carboniferous formation is followed by superior deposits, without the appearance of such disturbances between their respective periods; but apparently this case belongs to the class of exceptions already noticed.* That disturbance was general, is supported by the further and important fact of the destruction of many forms of organic being previously flourishing, particularly of the vegetable kingdom.

* "Some of the most considerable dislocations of the border of the coal fields of Coalbrookdale and Dudley happened after the deposition of a part of the new red sandstone; but it is certain that those of Somersetshire and Gloucestershire were completed before the date of that rock."—*Philips*.